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NASA LUNAR DUST WORKSHOP

Mechanical Systems Splinter Group Discussion Items

Overarching Question: What are the key (significant) issues associated with operating mechanical systems successfully in the lunar dust environment?

A. What types of mechanisms, systems and operational scenarios are envisioned in the lunar environment?

1. What types of mechanical systems and components are likely needed for operation on the lunar surface that could be affected by the lunar dust environment?
    - Bearings
    - Bushings
    - Gears
    - Ball-screws
    - Seals (elastomeric, metallic)
    - Lubricants
    - Other rotating surfaces
    - Fasteners (latches, clamps, bolts, etc.)

    Hypothesis 1a: Effects of lunar dust on mechanical systems in general can be boiled down to just a handful of mechanical components that if designed to mitigate dust can be tested / demonstrated in the appropriate dust environmental conditions.

    Hypothesis 1b: The lunar dust environment poses a mission success risk to the operation of mechanical systems that can be adequately mitigated with appropriate design features, and appropriate environmental qualification testing.

2. What mechanical system operational scenarios could be complicated/impacted by the lunar dust environment?
    - Maintenance and repair in the presence of dust
    - Dust accumulation on surfaces affecting power generation, thermal/optical properties necessary for heat retention/rejection
    - Exposed connectors, seals and sealing surfaces of umbilicals

    Hypothesis 2: A number of mechanical system operational scenarios will be complicated by the presence of dust.

3. What types of practical design solutions can be employed to help mitigate the performance degrading effects of lunar dust in mechanical system operation?
    - Seals to minimize lunar dust getting into mechanisms
    - Coatings that will repel/propel dust
    - Electrical grid pattern to propel dust from surfaces

- Material selection
- Covers

Hypothesis 3: Relatively simple design mitigations can be employed to lessen the extent of the lunar dust environment impacting lunar mechanical systems performance and operation.

B. How much more do we need to know about lunar dust?

4. What are the most significant properties (physical characteristics and composition) of lunar dust that could affect the operation and performance of mechanical systems in the lunar dust environment?
    - Particle morphology (abrasiveness, size distribution, etc)
    - Chemical composition
    - Electrostatic properties
    - Thermal/optical properties
    - How much and what size will be lofted (electrostatically, tribomechanically) to become potential hazard to mechanisms, and/or deposited on surfaces

Hypothesis 4: The lunar dust properties can be boiled down to just a few physical, chemical and electrical characteristics that are most germane to the operation and performance of mechanical systems.

5. What further measurements and testing are required to understand lunar dust and its effect on mechanical systems intended for operation in a lunar environment?
    - Abrasiveness and as function of particle size
    - Particle size distribution (especially the fraction < 20 μm)
    - Chemical composition and as function of particle size (especially the fraction < 20 μm)
    - Electrostatic properties and as function of particle size (especially the fraction < 20 μm)
    - Thermal/optical properties as function of particle size (especially the fraction < 20 μm)

Hypothesis 5: The composition and physical characteristics of lunar regolith can be sufficiently emulated by well designed simulants. Additionally the simulant composition can be tailored for specific mechanical component test objectives.

C. What is the appropriate set of development and qualification tests necessary for demonstration of successful mechanical systems operation in the lunar dust environment?

6. What is a suitable test environment capable of simulating appropriate characteristics (germane to mechanical systems) of lunar dust in mechanical system operation?

- Thermal/Vacuum
- Ground based
- In-situ during precursor mission
- lunar regolith
- lunar simulant
- Plasma environment

Hypothesis 6a: Specific in situ measurements of the lunar environment, including dust, will be required to validate design analysis and ground based verification testing of lunar mechanical systems.

Hypothesis 6b: The lunar environment can not be sufficiently emulated on Earth, therefore system verification testing will rely to some extent on extension by analysis.

7. What testing techniques and facilities should/could be used to conduct development testing to determine sensitivity of mechanical system operation in the lunar dust environment?
   - Are there any past and present testing techniques (Apollo, Shuttle, ISS) for a dust/sand environment?
   - Are there standard test methods that exist in the Aerospace industry or DOD for the dust environment?
   - What are standard Tribology testing techniques for bearings, gears, lubricants, and other rotating surfaces (SOT, block on ring, etc)?

Hypothesis 7: Relatively simple test techniques can be employed to understand sensitivity to lunar dust in the operation and performance of mechanical system components.

8. What testing techniques and facilities should/could be used to conduct mechanical system flight hardware qualification testing to demonstrate performance in the lunar dust environment?
   - Thermal/vacuum dust chamber with simulants
   - Dust box

Hypothesis 8: Once sensitivities are understood and mitigation strategies have been defined a robust qualification test program can be developed to verify mechanical system performance in the lunar dust environment.

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Mechanical System Splinter Group Agenda:

Day 1: **Topic**	**Presenter**	**Duration**
Introduction/Objectives/Process	J. McManamen/M. Hyatt	15 min
Briefing: Overview of NESC Mechanical Systems Lunar Dust Proposal	Mike Dube	15 min
Briefing: Overview of ETDP Lunar Dust Project	Mark Hyatt	15 Min
Briefing: Lunar Mechanical Systems and operational scenarios	Jeff Hagen/JSC	30 Min
Discussion: Types of mechanical systems, components and lunar operation scenarios envisioned	All	60 min
Break		15 min
Discussion: How much more and do we need to know about lunar dust with regard to mechanisms	All	60 min
Summary: Day 1 key findings and recommendations	J. McManamen/M. Hyatt	30 min
Day 2:		
Introduction/Summary recap of Day 1	J. McManamen/M. Hyatt	15 min
Discussion: Potential mitigations that can be employed	All	90 min
Break		15 min
Discussion: Types of development testing to understand sensitivities and potential flight hardware qualification testing requirements	All	90 min
Summary: Day 2 key findings and recommendations	J. McManamen/M. Hyatt	30 min
Day 3:		
Introduction/Summary recap of Day 2	J. McManamen/M. Hyatt	15 min
Discussion: Continue discussion on mitigation strategies and testing	All	120 min
Final Summary: Key findings and recommendations	J. McManamen/M. Hyatt	60 min